DIAMOND PROJECT

Autonomous vehicles through gender perspective glasses

→ Designing a more **inclusive** and **gender-fair** autonomous car

Authors

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DIAMOND Project

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Executive summary

When this document was initially conceived, the main foreseen contents were linked to the (potentially differentiated) emotional needs of women and men in automated vehicles. The research and work developed during the DIAMOND project has contributed to widen the scope of this report to other fields beyond that of the emotions. In this sense, such aspects as the unfairness and inequality present in current cars need to be highlighted in a work of these characteristics.

In addition, as Connected Automated Vehicles (CAVs) are still a product that is under development, we have considered it interesting to mention tools and methodologies in the guidelines that could be used to gain more knowledge of the needs and requirements of potential CAV passengers, especially girls and women. By doing so, we wanted to provide useful information which could contribute to improving fairness and equality in autonomous vehicles based on human factors and participatory design.

This report contains the complete contents of the guidelines entitled "Autonomous vehicles through gender perspective glasses. Designing a more inclusive and gender-fair autonomous car". The structure of the guidelines is based on the following main blocks:

- Introduction and definitions
- Results and recommendations

Although we are aware that the information presented in this report covers only a tiny albeit important part of all that is going on in the field of CAVs, our purpose is in any case multiple:

- Those familiar with the concepts of gender equality and fairness will be able to gain technical knowledge about CAVs, and to understand how their vision and knowledge is important to develop better vehicles.
- Those familiar with the automotive sector and those who are aware of all the challenging developments taking place in autonomous vehicles will benefit by its human-centered approach which stresses women's needs and perceptions.
- Those absolutely new to either of the two fields will discover to what degree the development of the automotive sector means a breakthrough in terms of the traditional concept of a privately owned vehicle. They will also identify the potential of applying the concepts of equality and fairness to such a technological field.

In any case, we hope that anyone approaching this work will find fresh ideas and concepts that they can apply to their daily work, no matter whether they are a designer, a car manufacturer or a policy maker.

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DIAMOND PROJECT

Block 1 → Introduction and *definitions*

Authors

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1.1 Why is this guide necessary?

The need and the opportunity

The increase of automation in vehicles is a reality, embedded in other social, economic and technological trends. And, although fully automated vehicles are still under development (Olsen & Sweet, 2019), they will be a reality in the near future, and the details of their design, configuration and functionalities remain open. In the automotive sector, human-centered design has tradicionally been overshadowed by technology-led innovation (Saunders, 2019). What we know so far is that technology push and design for the "average man" has raised serious safety issues for certain groups, notoriously women. The fact that women's needs and requirements are not properly addressed is not a situation that is exclusive to the automotive industry as (Criado-Pérez, 2019) brilliantly explains in her book *Invisible Women: Exposing Data Bias in a World Designed for Men*. With new forms of big data and automated and micro-mobility changing the scene fast, leaders in mobility need a strong human-centered framework if they are to navigate the technological evolutions coming from everywhere (Saunders, 2019). And of course, this human-centered innovation has to be gender inclusive.

In the collective imaginary, flying carpets would be the first obligatory reference to autonomous vehicles. They combined two once-fantastic dreams: autonomous vehicles and flight. Looking for a specific date, we could pinpoint Futurama 1939, the New York World's Fair, where General Motors displayed its concept of a self-driving car guided by an automated highway system (Weber, 2014). Hardly fifty years before that, Karl Benz had patented the Benz Patent-Motorwagen (1886) and some thirty years earlier, Ford had begun to produce the model Ford-T in the USA (1908), the first affordable car in history thanks to the introduction of assembly line production. And even in those times we need to be aware of the importance of two women. First, Bertha Benz, who sponsored the patent of her husband and suggested important technical improvements to it after being in 1888 the first person to drive an automobile a significant distance (Wikipedia, 2021). And second, the suffragist Lady Norman, who experienced the convenience of using her powered scooter in 1916 which allowed her a much wiser use of her time to reach her working place on time in the centre of London (Estévez, 2019). That was one hundred years before the electronic scooters and other personal electronic devices became popular in our streets.

Since then, innovation within the automotive sector has created safer, cleaner, and more affordable vehicles, but progress has been mainly incremental (Anderson et al., 2014). One of the key elements of innovation in terms of autonomous vehicles is the introduction over time of increasing degrees of driver assistance. The need to organize the presence and combination of different assistance elements, from active safety systems, to driving support features and automated driving systems, has led to a proposal for different levels of automation classification according to the technological capabilities and the need for human involvement (Kyriakidis et al., 2015). Basically, vehicle automation levels range from driver assistance technologies (e.g. staying in lane, parking assistant, etc.) to full vehicle automation, in which the vehicle is responsible for all critical safety functions (Olsen & Sweet, 2019).

Without going into too much detail, it is important to mention some aspects. From a geographical perspective there have been three main development hubs: (1) *Europe* (with known initiatives in UK, Germany and Italy), (2) *US* and (3) *Japan*. To which, despite its late entry, we need to add China. Its self-driving car industry has taken off over the past decade and now is receiving backing from both the government and industry heavyweights (Huld, 2021).

On the other hand, if we analyse the entities participating in this development, these were mostly universities and research centers at first. Later, companies from inside and outside the automotive sector became involved as well. From a technology point of view early efforts were highway-automation systems but not really robots or driverless cars. Later the focus was directed on cars once again. And now we have a blurred border zone as vehicles gain intelligence and autonomy but at the same time increase the connection to and communication with other vehicles (V2V) and also to infrastructure (V2I). Several authors have given their visions on the recent history of autonomous vehicles (Billington, 2018; Bishop, 2020; Bogost; 2014; Gammon, 2016; Nguyen, 2019).

These are four initiatives which have been relevant in the development of autonomous vehicles:

PROMETHEUS

The Eureka PROMETHEUS project

The Eureka PROMETHEUS project (PROgraMme for a European Traffic of Highest Efficiency and Unprecedented Safety, 1987–1995) was the largest R&D project ever in the field of driverless cars. It received 749 million euros in funding from the pan-European research organization Eureka and defined the state of the art of autonomous vehicles. Numerous academic organizations and car manufacturers participated in this project.

The contribution of Ernst Dickmanns (Delcker, 2018), and his team at the Bundeswehr Universität München, was beyond doubt more than noteworthy. In 1994, their twin vehicles VaMP and VITA-2 drove more than one thousand kilometers on a Paris multi-lane highway in standard heavy traffic at speeds of up to 130 km/h. The achievements represented a real breakthrough: driving in free lanes, driving in a convoy, automatic tracking of other vehicles, and lleft and right lane changes involving the autonomous overtaking of other cars. In 1995, re-engineered autonomous S-Class Mercedes, embarked on a 1000-mile trip from Munich in Bavaria to Copenhagen in Denmark and back, using saccadic computer vision and transputers to react in real time. The robot achieved speeds in excess of 175 km/h on the German Autobahn. Despite being a research system which did not place the emphasis on long distance reliability, it drove up to 158 km without any human intervention.

Connected Automated Driving

This is the reference European CAV network. It was developed as part of the Horizon 2020 Action ARCADE (Aligning Research & Innovation for Connected and Automated Driving in Europe). This Knowledge Base gathers scattered information held by a broad network of CAD stakeholders to establish a common baseline of CAD knowledge and provide a platform for a broad exchange of knowledge. It has become a one-stop shop for CAD data, knowledge and experiences in Europe and beyond.

The Knowledge Base is ever evolving and growing along with the existing body of knowledge in the field. It promotes the sharing of knowledge, data and experiences for the development of connected and automated driving.

https://www.connectedautomateddriving.eu/

DARPA Grand Challenge project

At the start of the 21st century, the US military, which began getting involved in the development of autonomous vehicle technology during the ‘80s, announced the DARPA Grand Challenge, a long-distance competition in which 1 million dollars would be awarded to the team of engineers whose vehicle won the 150-mile obstacle course. Although none of the vehicles finished the course, the event was considered a success as it helped to spur innovation in the field. The agency also held several more competitions in subsequent years as a way to encourage engineers to further develop the technology. This initiative provided tremendous impetus, so much so that it was described as a complete tectonic shift.

https://en.wikipedia.org/wiki/DARPA_Grand_Challenge

Google

In this connection, the push given to this technological race to achieve an autonomous “everywhere, everytime” vehicle by Google since 2010, has been especially remarkable. Other companies working on autonomous vehicles development include UBER, Microsoft, Tesla as well as traditional car manufacturers such as Toyota, Volkswagen, BMW, Audi, General Motors, Ford and Honda (Nguyen, 2019, p.).

The vision and ambition

Autonomous Vehicles, Driverless cars or Connected and Automated Vehicles (CAVs), to use the EU jargon, is not a new concept. For several decades, there have been important developments and resources devoted to reaching a fully automated vehicle. Although the degree of uncertainty is high, it seems clear that full autonomous vehicles, still under development (Olsen & Sweet, 2019), will be a reality in the near future. In this sense different studies have set different dates and degrees of penetration. Thus, for (Böhm et al., 2017) highly automated vehicles will be affordable and commonplace in the 2040s while in a study published by (Kyriakidis et al., 2015) 69% of respondents to a survey estimated that fully automated driving will reach a 50% market share between now and 2050.

What does seem to be a shared global vision is that vehicle technology ought to be permitted if and when it is equal or superior to average human drivers. For the European Union, Connected and Automated Mobility - CAM provides a unique opportunity to make our transport systems safer, cleaner, more efficient and more user-friendly[1]. But in order to assess whether or not it is superior we should draw up a list of pros and cons. For some authors, superiority is assessed mainly in terms of safety and security. However, the literature has gone beyond this, identifying potential benefits and drawbacks in different areas (societal, technical, regulatory, economic, environmental and ethical). It would be impossible to list them all. Table 1 summarizes some of them.

Potential benefits	Potential drawbacks
Machines don't get tired	People may forget how to drive manually
Self-driving cars make fewer mistakes	High R&D costs
Autonomous cars follow traffic rules	Technology not yet mature enough
No danger from drunk drivers	Technical errors

Source: https://environmental-conscience.com/self-driving-cars-pros-cons/

[1] https://digital-strategy.ec.europa.eu/en/policies/connected-and-automated-mobility, 08/10/2021

Table 1

Can find the fastest route	Moral concerns
No accidents due to emotional behavior	Insurance problems
Fuel savings	Low level of public acceptance
Less air pollution	Danger of hacking attacks
Car theft reduction	High purchase price
Economic advantages	Privacy concerns

Table 1. Potential benefits and drawbacks of CAVs

In addition to the above information, some doubts emerge in relation to CAVs: “it is unclear whether society will benefit or suffer from them” (Hohenberger et al., 2016). [CAVs] might be superior to traditional cars, and hence should be supported compared to using conventional cars. Implementing automated cars should not reduce societal and political approaches to promoting cycling, walking or using public transport (Hohenberger et al., 2016). Expanding the intelligence and autonomy of such vehicles is not the only concern when we talk about mobility. There is a clear push towards a more sustainable and integrated mobility (Saunders, 2019). With 1.2 billion cars on the planet causing massive pollution and congestion, the drive toward Mobility as a Service (MaaS) aims to greatly reduce the number of privately-owned cars and improve cities (Kalms, 2019). However, although alternatives to driving and car ownership are increasingly being introduced to consumers, whether such services are readily available as effective ways to replace driving and car ownership is still a very open question (Abraham et al., 2016).

As CAVs are a field under development, we have the opportunity to implement a gender vision to traditional ergonomics and safety elements while dealing, for example, with the future HMI that will make it possible to regain or transfer control or perform different Non-Related Driving Tasks (NRDT) inside the vehicle. A gender approach incorporates important concepts such as the mobility of care or trip-chaining in contrast to simple commuting in a changing paradigm for all concerned, from drivers and to occupants or passengers. The definition and importance of these concepts are developed in the different points of the guidelines.

Purpose and scope of this guide

The aim of the guidelines developed in the framework of the DIAMOND project[2] is to heighten awareness, identify key points and strategic lines for the development of fairness for women in CAVs. Of course, we are aware that the information presented in this report only covers a tiny albeit important part of all that is going on in the field of CAVs, namely gender fairness from a perspective of human factors applied to Automated Passenger Cars for personal use, minibuses or driverless cars. In any case the purpose is multiple:

- Those familiar with the concepts of gender equality and fairness will be able to gain technical knowledge about CAVs, and to understand how their vision and knowledge is important to develop better vehicles.
- Those familiar with the automotive sector and those who are aware of all the challenging developments taking place in autonomous vehicles will benefit by its human-centered approach which stresses women's needs and perceptions.
- Those absolutely new to either of the two fields will discover to what degree the development of the automotive sector means a breakthrough in terms of the traditional concept of a privately owned vehicle. They will also identify the potential of applying the concepts of equality and fairness to such a technological field.

In any case, we hope that anyone approaching this work will find fresh ideas and concepts that they can apply to their daily work, no matter whether they are a designer, a car manufacturer or a policy maker. All in order to produce fair, safe and comfortable CAVs for all.

[2] The DIAMOND project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 824326. https://diamond-project.eu/

How was this guide developed?

This guide has been developed within the framework of the DIAMOND project, and incorporates valuable input from the SUaaVE[3] project thanks to the close collaboration between the IBV and the RUG.

The use of different methods together with the results obtained in the DIAMOND project, have permitted the identification of the key points and strategic lines, from a human factors perspective, for the development of gender fairness in AVs.

The **bibliographic review** and collaboration with SUaaVE project focused on: (1) *the gender perspective in mobility patterns, ergonomics and safety*; (2) *acceptability and emotions related to autonomous vehicles*; and (3) *technology and design to cover old and new needs and potential functionalities* which may come up with the development of the AV.

Focus groups were used to complete the whole framework of the acceptance of AVs and advanced technologies in vehicles, as well as to better understand the different patterns of mobility and how such mobility is influenced by having to take care of children or other dependents.

[3] SUaaVE project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 814999.

The Human Autonomous Vehicle (HAV) (Belda-Lois et al., 2021), a dynamic driving simulator developed by IBV, was used to emulate scenarios in which passengers' emotions were monitored. Forty potential AV users, balanced in terms of gender and having (or not) family dependents, participated in and answered an extensive questionnaire.

Strategic lines were structured following the Gender Fairness and Inclusiveness Maturity Model developed in the DIAMOND project: (1) *capacity to meet required needs*, (2) *accessibility* and (3) *safety and security*.

1.2 Terms, concepts and definitions

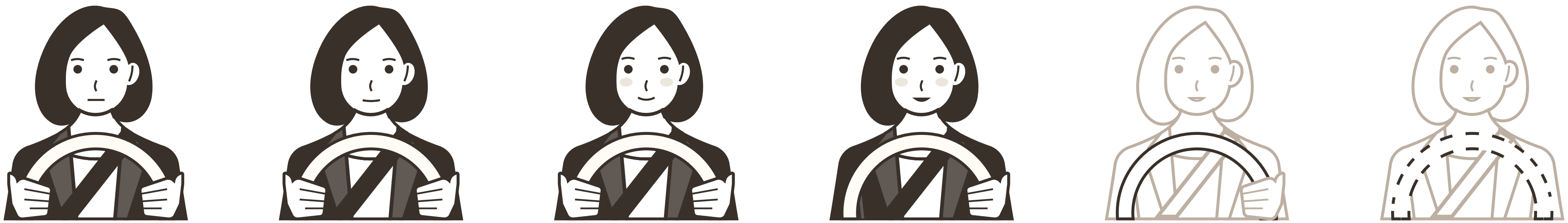
This section describes a reduced number of key definitions: (1) Connected Automated Vehicles (CAVs), (2) Gender and Sex, (3) Fairness and Equality and (4) Human Factors. Other definitions, which are introduced in other parts of the text, are required to understand the content in terms of the results of the Diamond project or recommendations for more inclusive and fair CAVs.

1.2.1 Connected Automated Vehicles (CAVs)

Several taxonomies have been developed that differentiate among levels of automation (e.g., SAE International, 2018; NTSA, 2016). The Society for Automotive Engineers generated a taxonomy that ranges from 0 (No Automation) all the way to 5 (Full Automation), with intervening numbers indicating increasing levels of automated technology, see Figure 1 and Figure 2 for more detail.

Society of Automotive Engineers (SAE) automation levels

Fig. 1



lvl. 0

No automation

Zero autonomy, the driver performs all driving tasks.

lvl. 1

Driver assistance

Vehicle is controlled by the driver, but some driving assist features may be included in the vehicle design.

lvl. 2

Partial Automation

Vehicle has combined automated functions, like acceleration and stee-ring, but the driver must remain engaged with the driving task and monitor the environment at all times.

lvl. 3

Conditional Auto-mation

Driver is a necessity, but is not required to monitor the environment. The dri-ver must be ready to take control of the vehicle at all times with notice.

lvl. 4

High Automation

The vehicle is capable of performing driving functions under certain conditions. The driver may have the option to control the vehicle.

lvl. 5

Full Automation

The vehicle is capable of performing all driving functions under all condi-tions. The driver may have the option to control the vehicle.

Figure 1. Representation of the automation levels according to the SAE

Fig. 2

	SAE lvl. 0	SAE lvl. 1	SAE lvl. 2	SAE lvl. 3	SAE lvl. 4	SAE lvl. 5
What does the human in the driver's seat have to do?	You are driving whenever these driver support features are engaged – even if your feet are off the pedals and you are not steering.			You are not driving when these automated driving features are engaged – even if you are seated in "the driver's seat".		
	You must constantly supervise these support features; you must steer, brake or accelerate as needed to maintain safety.			When the feature requests you must drive.	These automated driving features will not require you to take over driving.	
	These are driver support features			**These are automated driving features**		
What do these features do?	These features are limited to providing warning momentary assistance.	These features provide steering OR brake/ acceleration support to the driver.	These features provide steering AND brake/acceleration support to the driver.	These features can drive the vehicle under limited conditions and will not operate unless all required conditions are met.		This feature can drive the vehicle under all conditions.
Example features	- Automatic emergency braking - Blind spot warning - Lane departure warning	- Lane centering OR - Adaptative cruise control	- Lane centering AND - Adaptative cruise control at the same time	- Traffic jam chauffeur	- Local driverless taxi - Pedals/steering wheel may or may not be installed	Same as level 4, but feature can drive everywhere in all conditions.

Figure 2. SAE J3016™ niveles de automatización de la conducción™

Source: SAE International 2021.
http://sae.org/standards/content/j3016_202104

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According to (Fisher et al., 2020) at the lower end of the scale (Levels 1-2). Driving Support Features (DSFs) perform a portion of the driving task, controlling lateral or longitudinal control (Level 1) or both (Level 2), with the human having ultimate responsibility to monitor the situation and intervene as needed. Examples are Adaptive Cruise Control and Lane Centering. In Level 3, the Advanced Driving System (ADS) performs the entire driving task within the defined Operative Driving Domain (ODD), but a human driver is required to be available to take over control when requested by the system. For Levels 4 and 5, the ADS takes full responsibility for vehicle control; the vehicle, not the driver, is driving. In the case of Level 4, this is conditional and focused on a specified ODD, whereas for Level 5 it is unconditional -i.e., the vehicle can automatically handle all driving situations now handled by human drivers. For the foreseeable future, deployment of highly automated systems will be at Level 4. While Level 5 is useful as a logical endpoint of the scale, there may not be a sufficient business case to actually deploy "anywhere, anytime" Level 5 systems, i.e., society and markets may not see the need for that last 0.0001% of ADS capability.

It is also important to note that a particular vehicle may operate at different levels of automation depending on the operational environment and task at hand (Fisher et al., 2020). The general feeling of AVs is that their autonomy will be associated with the deployment of other technologies, connected to other cars and to the infrastructure, in potentially shared services and electrically powered. (Diels et al., 2017) uses the acronym CASE to refer to a Connected-Autonomous-Shared-Electric mobility[1].

[1] CASE Framework: Our Customer-Centric Approach to smart Mobility. By APTIV. https://www.aptiv.com/en/newsroom/article/case-framework-our-customer-centric-approach-to-smart-mobility

1.2.2 Shared Automated Vehicles and Nomadic Passengers

CAVs will most probably come with a change in the paradigm of mobility and car use. Different business models have been studied and analyzed (Stocker & Shaheen, 2017), from shared privately owned vehicles to robotaxis. If we are considering what services may come with fully automated vehicles, we also need to think about the new potential drivers, especially those who are not able to drive conventional cars, from children to people with some sort of disability or older people with compromised driving skills.

Shared mobility and shared automated vehicle

Shared mobility refers to the shared use of a vehicle, bicycle, or another low-speed mode of transport that enables users to have short-term access to transportation modes on an "as-needed" basis. Shared mobility includes services like carsharing, bike sharing, scooter sharing, on-demand ride services, ridesharing, micro transit, and courier network services. Shared mobility services have been growing rapidly around the world (Stocker & Shaheen, 2017).
The term shared automated vehicle (SAV) puts the emphasis on the fact that the use of the vehicle is shared between multiple users, and that this use will probably determin its design. That may make SAV different from other type of driverless cars or robotaxis.

What is important about the advancement of AV technology and the growth of shared mobility services is the possibility of providing important alternatives to conventional transportation, and the fact that they have the potential to alter the way in which people move around cities. Some analysts believe the first AVs that will be introduced to the broader public could occur as part of a shared-fleet service model, instead of through privately-owned AVs (Stocker & Shaheen, 2017).

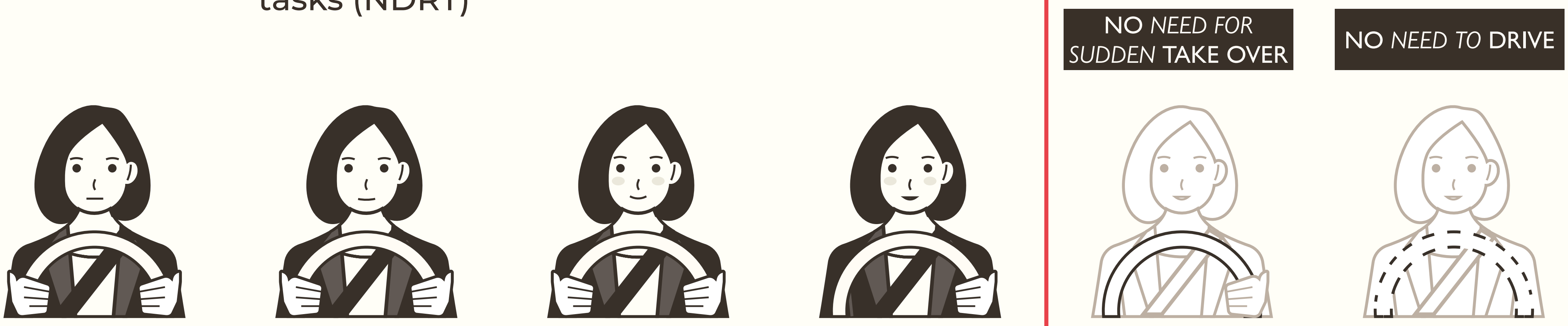
Nomadic passengers

There has been much speculation regarding the effects of shared automated mobility on traveler behavior, urban layout, congestion, and the environment. While the impacts of such a system are unknown since no large-scale public SAV service exists today, there are many academic studies that explore potential SAV scenarios (Stocker & Shaheen, 2017).

In any case, we want to use the common concept of all these scenarios and that is the existence of a nomadic traveler. A diverse passenger, who travels with their belongings, and in scenarios where the vehicle and the trip or only the vehicle may be shared. Thinking about a nomadic traveler implies introducing flexibility into the layout and the configuration of the car. Although some studies have addressed the different needs of users, such as people with disabilities (Bayless & Davidson, 2019), little has been written about the differentiated needs of women and girls in CAVs.

1.2.3 Non-driving related tasks (NDRT)

Fig. 3



lvl. 0

No automation

Zero autonomy, the driver performs all driving tasks.

lvl. 1

Driver assistance

Vehicle is controlled by the driver, but some driving assist features may be included in the vehicle design.

lvl. 2

Partial Automation

Vehicle has combined automated functions, like acceleration and steering, but the driver must remain engaged with the driving task and monitor the environment at all times.

lvl. 3

Conditional Automation

Driver is a necessity, but is not required to monitor the environment. The driver must be ready to take control of the vehicle at all times with notice.

lvl. 4

High Automation

The vehicle is capable of performing driving functions under certain conditions. The driver may have the option to control the vehicle.

lvl. 5

Full Automation

The vehicle is capable of performing all driving functions under all conditions. The driver may have the option to control the vehicle.

Figure 3. Representation of the need to control a vehicle by a person in the higher levels of automation

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CAVs (high or full automated) will not require the engagement of the passenger as a "driver", at least during most of the trip, as there will longer be any need for him or her to suddenly take over the control of the vehicle (see Figure 3). Releasing the passenger from the duty of driving opens up the possibility of performing different activities while travelling from place to place, irrespective of the nature or duration of the trip. We will refer to these activities as Non-Driving Related Tasks (NDRT).

Traditionally, the study of NDRT has focused on their effect on the transition from not driving to taking over the control of the vehicle, as this transition might imply key safety issues (Yoon & Ji, 2019), specifically at lower levels of automation. Once we assume that there will be no need to suddenly regain such control, under the L4 and L5 schemes, we can widen the focus and categorize these NDRT from another perspective and see possible implications in other terms. What is the relationship between the layout and the different NDRT? Are there any possible implications from a design perspective? Are women and men willing or do they need to perform the same type of NDRTs? Different research studies have at least partially addressed these questions. Audi's 25th hour project conceived three-time modes: productive time (for work), quality time (with one's family and friends), and down time (defined as watching a movie or playing a game). However, while the concepts of productive and down time may be quite clear and self-explanatory, the concept of quality time introduces extremely personal aspects of time spent in a car and may require a deep level of adaptability and personalization (Vlad, 2017).

(Parida et al., 2019) define a fully autonomous vehicle as a "living space", rather than just a mode of transportation. In such a space, we would have the possibility of using it as a place to work, a place to socialize, to relax, to meditate, to spend quality time with the family, to take a nap, and a whole lot more. This work applies the need for adaptability and personalization to particular aspects of design: "the interior of the vehicle and the vehicle's seats would be reconfigured and redesigned in a different way, compared to conventional vehicle interiors until now". To reconfigure and adequately adapt the reduced space of the vehicle, a lot of importance will need to be given to human anthropometry. Consideration of the rapidly changing physical attributes, sex, age and diversity of the future user will be highly important. Anthropometry may find new important aspects that have a direct input on development, providing the ability to evaluate complex seating concepts and thereby enabling new activities and creating a vehicle that is more than just a highly comfortable compromise for driving (Parida et al., 2019).

1.2.4 Key perceptions: acceptability & acceptance, trust and control.

Out of all the possible perceptions about CAVs, we have selected acceptability and acceptance, and also trust and control. CAVs are not all that different to other technologies, and specially now when we are probably witnessing their introduction, mostly as demonstrators or controlled trials. There may be a certain degree of overlapping between these concepts. We may not accept CAVs because we do not trust the technology. And we may not trust the technology because the feeling of losing control is too overwhelming for some users. We hope this first approach to these definitions will illustrate the inherent complexity.

Acceptability and acceptance

Different works have studied the factors influencing acceptance of automated technologies, for instance (Fisher et al., 2020) contains an international review of public opinion about self-driving cars. For them, if the predicted benefits of AVs will not materialize until they are acceptable to and accepted by society. Despite some variation across countries, the general public appears largely positive about the potential benefits that may be derived from AVs, although some significant concerns remain (e.g., in relation to safety) that may hinder their uptake and use.

In the literature, acceptability and acceptance are sometimes used interchangeably. We have taken the definition used by (Post et al., 2021). For them, acceptability refers to one's attitudes and evaluations before one has experienced a CAV, whereas acceptance refers to one's attitudes, evaluations and behavior after having experienced a CAV. Acceptability could be expressed as an attitudinal evaluation or intention (e.g. the willingness to ride in a CAV), while acceptance could both be expressed as an attitude and as actual behavior (e.g. purchasing a CAV). As those people who have had experience with a CAV mostly had such experiences in an experimental setting and not in real life, current literature will cover acceptability and not acceptance in the majority of the reviewed studies.

Acceptability may have other social components, not just vis-à-vis the drivers or the actual passengers but also others road users. There may also be some legal and ethical issues (Anderson et al., 2014) which we are not going to discuss in this guide.

In any case, what makes these two concepts important is the fact that, they precede their use, as is the case with other technological products. Therefore, understanding the key factors behind acceptability and acceptance, and whether there is any difference between how women and men interpret them, will help to develop better CAVs. We talk about this in points 2.2 and 2.3 of this guide.

Trust

The following paragraph gives a definition of trust by (Fisher et al., 2020):

Trust is a multi-faceted term that operates at timescales of seconds to years to describe whether people rely on, accept, and tolerate vehicle technology. Trust mediates micro interactions concerning how people rely on automation to engage in non-driving tasks to macro interactions concerning how the public accepts new forms of transport. Public acceptance may depend on the trust of incidental users, such as pedestrians who must negotiate with AVs at intersections, and drivers who must share the road with AVs.

Based on this definition, we can appreciate that this is a complex construct and that we are not just talking about the trust of drivers or passengers. That time may play an important role, and even that issues related to the need for building, calibrating, losing and repairing trust should be addressed too. Also, based on this definition we can link trust with NDRT, as passengers trust CAVs, they would be able to disengage from their driving functions and dedicate themselves to NDRT in a much more satisfactory way.

Control and perception of control

In addition to the concept of control in vehicles, understood as one person (or system) responsible for maneuvering the car and all (or part of) its possible functions and taking full (or partial) responsibility for it, we have already described the different levels of automation in point 1.2.1; we now need to talk about the perception of control.

The perception of control is “the belief that one has control over the vehicles’ behavior” although one may not be physically driving it, given that in high automation levels, more and more functions are allocated to the vehicle. To have this belief of having control we need to understand how the system works and how the driver-passenger may interact with it. (Fisher et al., 2020) defines the concept of function allocation and how this function distribution may be of a dynamic nature as there is not yet any system that is 100% capable of replacing the human in all road environments, and at all times. What we do know now is that autonomous vehicles are probably some way away from being a 100% anywhere anytime CAV, but maybe we are not so far from 95% (Fisher et al., 2020). And therefore, how control is performed or how it is transferred between the driver-passenger and the CAV may be determinant when it comes to performing any NDRT and the passenger’s satisfaction experience.

1.2.5 Sex and gender in engineering

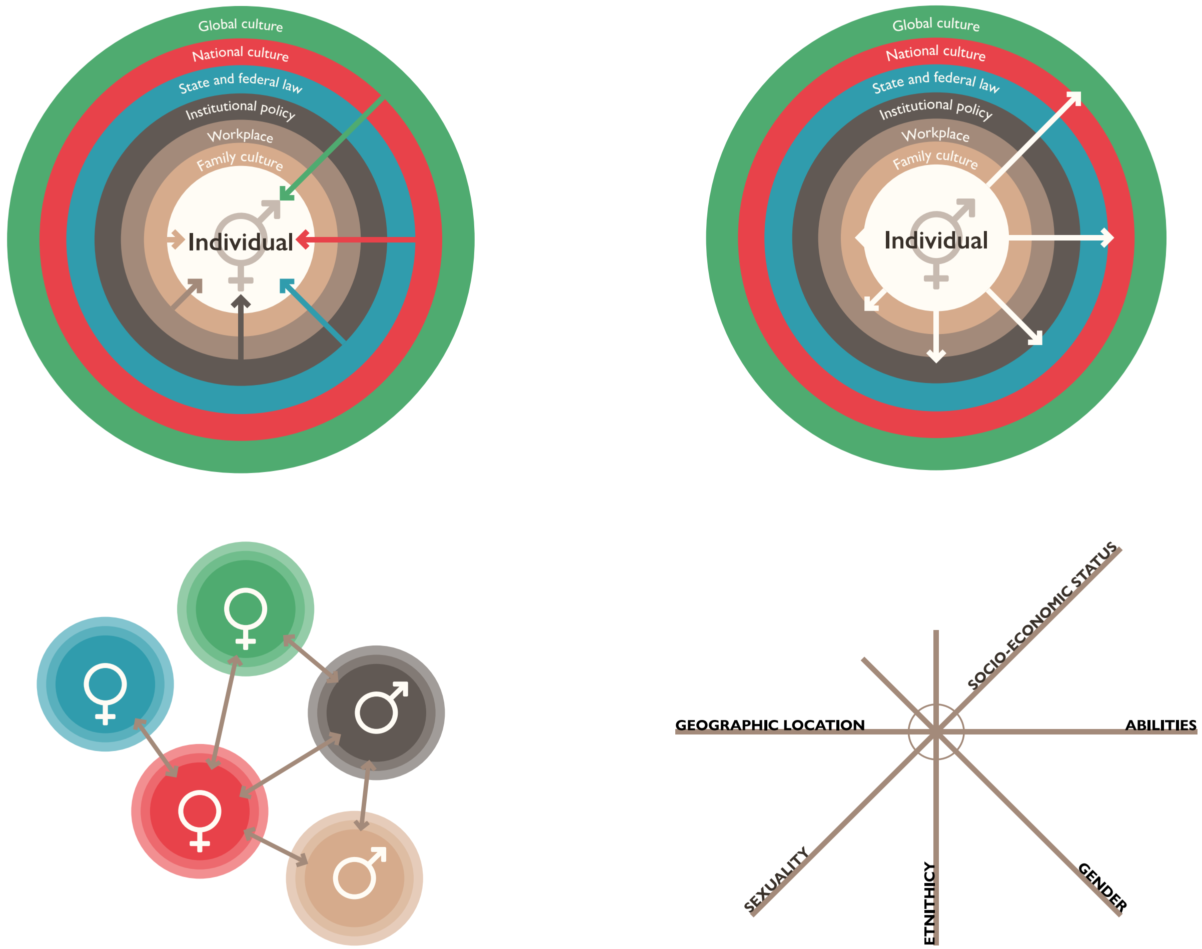
According to (Tannenbaum et al., 2019) the goal of sex and gender analysis is to promote rigorous, reproducible and responsible science. Incorporating sex and gender analysis into experimental design has enabled advancements across many disciplines, such as improved treatment of heart disease and insights into the societal impact of algorithmic bias.

Sex refers to the biological attributes that distinguish organisms as male, female, intersex (ranging from 1:100 to 1:4,500 in humans, depending on the criteria used) and hermaphrodite (over 30% of non-insect non-human animals). In biology, sex describes differences in sexual characteristics within plants or animals that go beyond their reproductive functions to affect appearance, physiology or the neuroendocrine, behavioral and metabolic systems. In engineering, sex includes anthropometric, biomechanical and physiological characteristics that may affect the design of products, systems and processes. Gender refers to psychological, social and cultural factors that shape attitudes, behaviors, stereotypes, technologies and knowledge. Gender includes three related dimensions. Gender norms refer to spoken and unspoken rules in the family, workplace, institution or global culture that influence individuals. Gender identity refers to how individuals and groups perceive and present themselves within specific cultures. Gender relations refer to power relations between individuals with different gender roles and identities. Sex and gender interact in unexpected ways. Pain, for example, exhibits biological sex differences in the physiology of signaling. Pain also incorporates sociocultural components in how symptoms are reported by women, men and gender-diverse people, and how physicians understand and treat pain according to a patient's gender.

Our interest in talking about sex differences and gender roles is to make sure that we put on gender-sensitive glasses so that women's needs and preferences are not invisible when it comes to defining the requirements for AVs to promote an equal approach that helps to mitigate the existing inequalities in the mobility field - This is the main objective of the DIAMOND project.

There are different and interesting examples of the application of a gender approach to innovation in different fields. One outstanding initiative comes from the University of Stanford and its portal 'Gendered Innovations in Science, Health & Medicine, Engineering, and Environment'[2]. In 2020, the European Commission published an interesting report on how an inclusive analysis improves and enhances the results of research and innovation[3].

Fig. 4



Source: (European Commission. Directorate General for Research and Innovation, 2020)

Figure 4. Representation of gender norms, identities, relations and intersectionality.

[2] https://genderedinnovations.stanford.edu/what-is-gendered-innovations.html

[3] https://genderedinnovations.stanford.edu/GI%202%20How%20Inclusive%20Analysis%20Contributes%20to%20R&I.pdf

Taking the definitions given in this report (represented in Figure 3) we can complete the whole framework:

- **GENDER NORMS** are produced through social institutions (such as families, schools, workplaces, laboratories, universities or boardrooms), social interactions (such as those between romantic partners, colleagues or family members) and wider cultural products (such as textbooks, literature, films and video games).
- **GENDER IDENTITIES** relate to how individuals or groups perceive and present themselves in relation to gender norms. Gender identities may be context-specific and interact with other identities, such as ethnicity, class or cultural heritage.
- **GENDER RELATIONS** relate to how we interact with people and institutions in the world around us, based on our sex and our gender identity. Gender relations encompass how gender shapes social int ractions in families, schools, workplaces and public settings, for instance the power relation between a male patient and a female physician.
- **INTERSECTIONALITY** describes overlapping or intersecting categories such as gender, sex, ethnicity, age, socioeconomic status, sexual orientation and geographical location that combine to inform an individual's identity and experience. The term has been expanded to describe intersecting forms of oppression and inequality emerging from structural advantages and disadvantages that shape a person's or a group's experience and social opportunities. Accordingly, researchers and engineers should not consider gender in isolation; gender identities, norms and relations both shape and are shaped by other social attributes.

In the automotive sector, the most remarkable initiatives have been promoted by Volvo. Volvo's Your Concept Car (YCC) was designed in 2004 by a team composed entirely of women[4]. The YCC resulted in 50 new solutions, several of which were technically forward-looking. The concept car clearly showed that cars are usually designed by men for men. The intention with the YCC was to highlight neglected needs and target groups that had not previously been prioritized in the design of cars. More recently, in 2019, Volvo's EVA initiative released 60 years of car accidents reports containing data segregated by gender, clearly showing the unfair situation women have to face, in terms for instance of the severity of the injuries they suffered in comparison with men under similar accident situations.

[4] https://www.media.volvocars.com/global/en-gb/media/pressreleases/5265

1.2.6 Fairness and equality for women

The DIAMOND project's main goal was to turn data into actionable knowledge with notions of fairness, in order to progress towards an inclusive and efficient mobility. But what should we understand by fairness? And why is it so important? According to (Friedman & Nissenbaum, 1996), a process is biased "if it systematically and unfairly discriminates against certain individuals or groups of individuals in favor of others. A system discriminates unfairly if it denies an opportunity or a good or if it assigns an undesirable outcome to an individual or a group of individuals on grounds that are unreasonable or inappropriate".

In the context of the DIAMOND project, equality of opportunities is related to issues such as accessibility to mobility (whether to a CAV or to a suitable public transport system). Therefore it can be understood as a state of fairness in which people are treated similarly, unimpeded by prejudices or unnecessary distinctions or barriers, except when they can be explicitly justified (e.g., cheaper fares for young or low-income people in public transport).

In other words, there should be fair and equal opportunity for all people, whatever their personal conditions (age, type of family, culture, religion, etc.), to have a safe, secure, effective and efficient mobility that meets their daily needs. With roots in the wider concept of social justice, equality of opportunity supports the idea that opportunities should not be restricted for different groups of people. Substantive equality of opportunities (substantive justice) implies that a "fair" system seeks to minimize not only explicit discrimination, but also indirect discrimination.

A rough working definition of fairness might therefore be: a state in which people are treated similarly, unimpeded by prejudices or unnecessary distinctions or barriers, except if they can be explicitly justified.

1.2.7 Human factors and Ergonomics

Under human factors or ergonomics, we may include a vast field of knowledge. The International Ergonomics Association (IEA)[5] gives the following definition:

The word ergonomics — "the science of work" is derived from the Greek ergon (work) and nomos (laws). Ergonomics (or human factors) is the scientific discipline concerned with the understanding of interactions among humans and other elements of a system, and the profession that applies theory, principles, data, and methods to design in order to optimize human well-being and overall system performance. The terms ergonomics and human factors are often used interchangeably or as a unit (e.g., human factors and ergonomics – HFE or EHF), a practice that is adopted by the IEA.

Although HFE practitioners often work within particular economic sectors, industries, or application fields, the science and practice of HFE is not domain specific. HFE is a multi-disciplinary, user-centric integrating science. The issues HFE addresses are typically systemic in nature; thus, HFE uses a holistic, systems approach to apply theory, principles, and data from many relevant disciplines to the design and evaluation of tasks, jobs, products, environments, and systems.

[5] https://iea.cc/what-is-ergonomics/

HFE takes into account physical, cognitive, sociotechnical, organizational, environmental and other relevant factors, as well as the complex interactions between the human and other humans, the environment, tools, products, equipment, and technology.

The reference European network on CAVs[6] highlights that the Human Factors thematic area is not only concerned with humans in the actual vehicles but also with humans around the vehicle and humans in surrounding vehicles. Examples of automation-specific topics are:

- Human modelling
- Harmonized in-vehicle design strategies as well as design strategies for the interaction of automated vehicles with external road users
- User-centered Design evaluation methodology
- Remote control operation
- Human state assessment

For the purpose of this guide, we will focus on:

- Physical ergonomics, because as we will see in point 2.1.2, they are not well addressed in current cars if we apply a gender perspective. Additionally,

[6] https://www.connectedautomateddriving.eu/thematic-areas/human-factors/

CAV proposes new challenges in relation to passenger safety and comfort associated to NDRT and shared mobility that it will shake up cabin design.

▪ Assuming that CAVs will be electric powered, besides the weight reduction challenge, how we achieve thermal comfortis going to be an issue because we already know from other fields that women and men have quite different experiences. How we reach thermal comfort is a capital research question we need to focus on considering: whether we are trying to heat or to cool the cabin (with the necessary energy consumption involved), new cabin and sitting materials or different preferences and needs in shared automated cars.

▪ Smart HMI, the interaction between the passengers and CAVs is going to be different from the modes of interaction we know and apply in conventional cars. This field is very interesting and is related to how passengers understand and trust the system and how the system adapts to them.

▪ Monitoring and interpreting the passenger state in order to understand what the passenger does and how the passenger feels, to respond taking the environment and context into consideration, are relevant factors for a proper smart HMI adaptation.

DIAMOND PROJECT

Block 2 → Results

Designing a more **inclusive** and **gender-fair** autonomous car

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DIAMOND Project

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Introduction to results

The objective of this block is to present recommendations and ideas to make CAVs more inclusive and fairer for women. This was indeed the main aim of the DIAMOND project in the use case of autonomous vehicles.

The first point of this block deals with the concepts of fairness and equality for women applied to CAVs. It emphasizes the idea of a long history of unfair designs and development in the automotive industry. It also shows a certain degree of hope introduced by Volvo's EVA initiative in 2019, which entailed the release of 60 years of car accidents reports, containing data segregated by gender. A rare but highly welcome move in this sector.

As we explained in Block 1 of this guide, acceptability and acceptance are sometimes used interchangeably. However, for the purpose of this guide we have differentiated them. While acceptability refers to one's attitudes and evaluation before one has experienced a CAV, acceptance could be expressed both as an attitude and as actual behavior (e.g., purchasing a CAV). In the SUaaVE project, the assessment focused on acceptability, and a complete acceptability model was built on the basis of a wide survey. By contrast, in the DIAMOND project we focused on the measurement of acceptance based on the participant's immersive experience in automated driving through a dynamic simulator. The second and third point of this block are devoted to explaining the acceptability model developed in the SUaaVE project, and the acceptance measures performed in the DIAMOND project.

The fourth part of this block describes the identified differentiated needs between men and women in relation to patterns of mobility and their preference and perception of use of time. We consider these may well be the key element for achieving a fair approach to CAVs for women. Here we talk about two key concepts: trip-chaining and mobility of care and the different perception relative to using time wisely under the label "Maximize my time!".

This block ends with recommendations for more inclusive and fairer treatment for women in terms of CAVs, built on the basis of the Fairness for Women and Maturity Model developed in the Diamond project[1]. Maturity Models are tools that are used in different fields to measure the ability of an organization for continuous improvement in a particular

[1] The detail of the Fairness Maturity Model for CAVs is available in the DIAMOND report D4.4 Integrated interdisciplinary analysis on https://diamond-project.eu/download/d4-4-integrated-interdisciplinary-analysis/

implemented by the organization. This model consists of four increasing inclusiveness levels around three main topics: (1) capacity to meet required needs, (2) accessibility, and (3) safety and security. The recommendations given are organized under these three topics.

2.1 Fairness and equality in CAVs, the approach of the DIAMOND project

2.1.1 Fairness and equality for women in the approach to CAVs

In point 1.2.6 we described the terms of fairness and equality for women in the context of the DIAMOND project, and we gave a rough working definition of fairness described as a state in which people are treated similarly, unimpeded by prejudices or unnecessary distinctions or barriers, except if they can be explicitly justified.

Based on this definition, we can formulate the following questions:

- *How does this concept translate to CAVs?*
- *What are the possible consequences and implications?*
- *Are today's cars fair for women?*

We will try to answer these questions in the following point and throughout this block of the guide.

2.1.2 Lack of fairness in the traditional automobile industry

Introduction of physical women differences in ergonomics

In the automobile industry, historically, men have been the norm. Cabin design safety systems have been designed and evaluated with a focus on a standardized male occupant with regard to anthropometric size and biomechanics. A car design based only on an "average man", increases safety risks and discomfort for women and other people with characteristics very far removed from this norm.

Regarding safety, (Linder & Svedberg, 2019) ran through EU regulatory crash-test requirements concluding that there is a gender gap that needs bridging between this aim and how vehicle occupant safety is actually assessed. Despite injury statistics showing that protection in the event of a crash is not equal for women and men, to date, the average male remains the only representative of the adult population in vehicle safety assessments.

In no test is an anthropometrically correct female crash-test dummy required. The seatbelt test, one of the frontal-collision tests, and both lateral-collision tests all specify that a 50th-percentile male dummy should be used (Linder & Svedberg, Wanna, 2018). There is one EU regulatory test that requires what is called a 5th-percentile female dummy, which is meant to represent the female population. Only 5% of women will be shorter than this dummy. But there are a number of data gaps. For a start, this dummy is only tested in the passenger seat (Linder & Svedberg, Wanna, 2018), so we have no data at all on how a female driver would be affected — something of an issue you would think, given women's "out of position" driving style. And secondly, this female dummy is not really female. It is just a scaled-down male dummy (Criado-Perez, 2019).

The situation is even worse for pregnant women. Testing with a pregnant crash-test dummy is still not government-mandated either in the US or in the EU. In fact, even though car crashes are the No. 1 cause of fetal death related to maternal trauma, we have not yet developed a seatbelt that works for pregnant women. Research from 2004 suggests that pregnant women should use the standard seatbelt; but 62% of third-trimester pregnant women don't fit that design (Criado-Perez, 2019).

One result of this unfairness in terms of design is the fact that when a woman is involved in a car crash, she is 47% more likely to be seriously injured than a man, and 71% more likely to be moderately injured - even when research factors as height, weight, seat-belt usage, and crash intensity are controlled. She is also 17% more likely to die. And it's all to do with how and for whom the car is designed (Criado-Perez, 2019).

Regarding safety aspects, which are critical in CAV acceptance, in May 2019, Volvo, the Swedish auto manufacturer, announced a company decision to make public some 60 years of research findings on car safety. Known as the EVA Initiative (the "Equal Vehicles for All" Initiative), Volvo has created a central digital library of all its research studies since 1970 and encourages other car manufacturers to make use of the research findings. By sharing this research and by letting everyone download more than 40 years of research, Volvo hoped this would lead to safer cars for everyone - regardless of gender and size (VOLVO, 2019).

Yet in 2021, most auto manufacturers still produce cars based exclusively on data from male crash test dummies.

Lack of fairness behind the lower women's acceptability of CAVs

Women are more likely to feel less safe than men in an autonomous car, and women are less likely than men to trust different semi-autonomous technologies, including self-parking, automatic emergency braking and adaptive cruise control. According to (Helmut Pflugfelder, 2018) female drivers may have good reason to believe that autonomous vehicles are not being designed with them in mind, in part because existing automobiles have not often been designed with them in mind. For example, until 2011, American automobile manufacturers used a fiftieth percentile male dummy for frontal crash tests; they essentially refused to test for different body types in some of the most dangerous kinds of accidents. Recent industry use of a fifth percentile female crash test dummy is simply the start of wide-scale changes to gender and body assumptions in design.

Additional developments should focus on user-centered, iterative testing with a broad range of human bodies and performances in mind. We could see a wholesale reconsideration of a range of driver-vehicle environments, including the suite of interfaces necessary for driver and passenger comprehension of autonomous technologies. Because these interfaces are at heart persuasive (in both active and passive ways), they represent existing and potential relationships between users and the host of new autonomous vehicle-related perceptions and tasks.

Another interesting point highlighted by (Helmut Pflugfelder, 2018) is the unbalanced situation in design teams where there is a clear predominance of male engineers and designers. While this situation does not necessarily lead to design problems, it does demonstrate the existence of a culture of normative masculinity within the automotive industry unlikely to manifest in thoughtful, gender-inclusive design. According to this author, in the case of autonomous vehicle projects, rethinking the functions and features of vehicles should also mean rethinking the fundamental makeup of design teams and committing to gender diversity within the automotive industry. As an exception to this, in point 1.2.5 we have already mentioned Volvo's Your Concept Car (YCC).

Some of the problems of unfairness and inequality in mobility would improve just by answering the following question: “does this solution serve both men and women?” Thinking about CAVs, we should ask how CAVs are going to improve this situation (considering not only privately owned vehicles but also shared CAVs). Therefore, the question to be answered should be: ***How can CAVs contribute to improving fairness and equality for women in terms of mobility?***

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2.2 Acceptability and perception of CAVs using the SUaaVE model

2.2.1 Key factors of acceptability and perception of CAVs

In order to build an acceptability model for CAVs a large survey was performed in different European countries during the development of the SUaaVE[1] project. The University of Groningen (RUG) has collaborated with the DIAMOND project providing a differentiated analysis of the database that resulted from the survey, enabling the identification of women's priorities to enhance the perception and improve the acceptability of CAVs. This point presents the SUaaVE acceptability model of CAVs, developed by RUG, and identifies women's priorities resulting from a close collaboration with the Instituto de Biomecánica de Valencia (IBV), the leader of the CAVs use case study in the DIAMOND project.

Several models aiming to explain technology and innovation acceptance include system and design features as acceptance predictors (e.g. the Technology Acceptance Model; Davis, 1993). With this in mind, we assume that the perceived characteristics of CAVs may also play a major role in their acceptance. The SUaaVE project analyzed the impact of seven main perceived CAV characteristics as predictors of their acceptability. It also assessed the importance given to these characteristics using a representative sample of European citizens and the degree by which it was perceived that CAV contributed to fulfill these attributes. The following list shows the seven components identified:

- *Perceived* SAFETY. The belief that the vehicle will be safe.
- *Perceived* CONVENIENCE. The belief that the vehicle will meet the user's driving needs.
- *Perceived* ENVIRONMENTAL SUSTAINABILITY. The belief that CAV will be environmentally friendly.
- *Perceived* PLEASURE. The belief that driving a CAV will be pleasant.
- *Perceived* CONTROL. The belief that one will have control over the vehicle's behavior.
- **Trust in CAV technology**. The belief that the vehicle will behave as intended.
- *Perceived* STATUS – ENHANCEMENT. The belief that owning or driving a CAV will increase one's status. This component had no impact on acceptability.

The above characteristics are supported in a large-scale survey (April 2020) at European level, used to feed a comprehensive CAV acceptability model. The final sample consisted of a total number of 3,783 participants aged from 18 to 72, with a mean

[1] SUaaVE project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 814999.

of 42.8 years, and spread relatively evenly (20.7% is 30 or younger, 19.8% is 55 or older). It involved six countries, the Netherlands (637), the United Kingdom (630), Germany (626), France (625), Spain (637), and Italy (628). In this survey, the main potential psychological factors influencing acceptability of CAV were measured to determine their significance and strength[2]. This significance and strength is used to explain the key factors of acceptability and perception of CAVs in the following point.

How will CAV be in the future? Women and men perceive that CAVs will be environmentally sustainable, trustworthy, convenient and safe. However, they do not feel that driving a CAV will be pleasant or will produce a feeling of having control over the vehicle's behavior. In a similar vein, owning a CAV is not perceived as an element that will increment one's personal status.

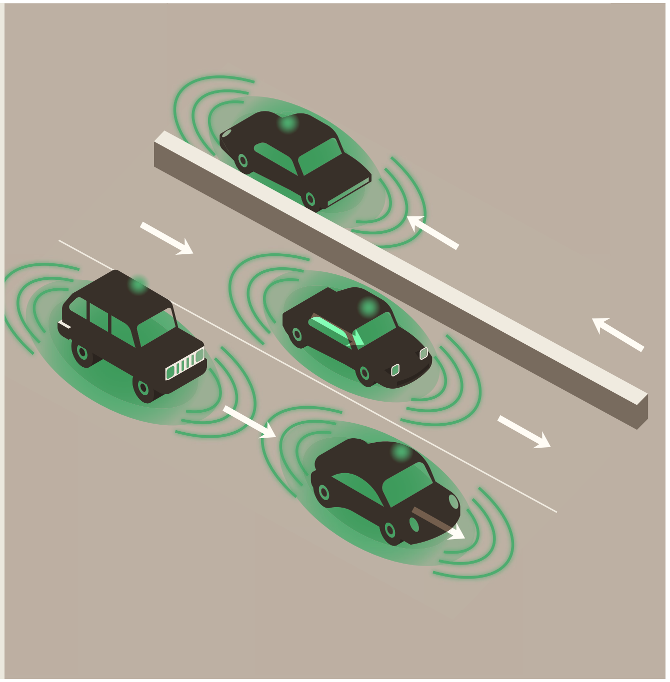
The contribution of the different attributes to the overall acceptability of CAVs is rated lower by women, except for pleasure where there is an equal level of perception. The highest differences, considering gender, are in the perception of trust, convenience and status which are notoriously lower for women. What does this mean? It means that women perceive that they will not be able to trust CAVs as much as men, and that they will meet their needs as passengers to a lower extent, and will contribute to a lower extent to the enhancement of one's personal status.

Figure 5 presents the results of the analysis of the strength of the different attributes impacting on the overall acceptability of CAVs. All the attributes have a positive impact, with the exception of status enhancement which has neither a positive nor a negative impact. That means that a higher perception that CAVs will be safe (convenient, controllable, etc.) in the future implies a higher acceptability of CAVs as a whole.

[2] The whole report with the results and detailed analysis of the survey data is included in the SUaaVE Public deliverable D1.2. "Model and guidelines depicting key psychological factors that explain and promote public acceptability of CAV among different user groups" (Post, Ünal and Veldstra, 2020) including relevant conclusions for the enhancement of CAV acceptability in EU populations. https://www.suaave.eu/wp-content/uploads/sites/17/2021/02/SUaaVE_WP1_D1.2_20200930_V100.pdf

Fig. 5

Perceived	
Safety	β = .300 (.019)***
Convenience	β = .256 (.018)***
Control	β = .035 (.013)**
Pleasure	β = .127 (.017)***
Sustainability	β = .200 (.014)***
Status enhancement	β = -.016 (.012)
Trust in CAV technology	β = .104 (.013)***



The most influential attributes in acceptability are safety, convenience, and environmental sustainability. They have the strongest linear impact on acceptability, meaning that the higher the perception of the presence of the attribute of safety, convenience and environmental sustainability in CAVs, the higher the acceptability of autonomous vehicles.

The next attribute in impact, at a short distance, is pleasure.

According to this, to improve the acceptability of CAVs manufacturers and marketers should focus on enhancing a good perception of CAV Safety, Convenience and Environmental Sustainability

Figure 5. Strength of attributes on acceptability of CAV. (Figure from SUaaVE public deliverable D1.2)

attributes. These top attributes should be emphasized in marketing, advertising and information campaigns.

When considering the importance of the different attributes individually, **Safety, Control and Trust** were considered as the three most important characteristics by women and men. In this case, control was notably important for women.

The particularity of Control and Trust. Control and trust are considered important but do not have a high lineal impact on acceptability. That means that **CAV has to be perceived as controllable and trustworthy** for their acceptability, due to their importance. In other words, control and trust are a must, and there is probably no need to increase them once the base line is overcome. The difficulty lies in defining the base line.

This, together with the fact that the perception of control in CAVs is low in the EU population, points to an interesting issue that needs to be addressed: the need to increase the perception of control, and the need to identify the optimal point of control. To add to the challenge, this optimal point may be different for different users (previous technological backgrounds, driving experience, abilities...) and may also depend on the driving environment (rain, traffic jam...).

The most important gender gap in the assessment of the importance of the different attributes is in environmental sustainability and control. In both cases, women consider them more important.

If we introduce the geographical variable into the analysis (see Figure 6), we can also identify differences between countries when answering the question "***The use of connected automated vehicles is acceptable***" in a scale from 1 – completely disagree, to 7 – completely agree. Although the acceptability for women is lower in all countries, on average 4.57 for women and 4.81 for men, when considering each country individually, The Netherlands and Germany score the lowest in terms of acceptability for women, followed closely by the UK and France. The greatest gender gap is in Germany, with a difference of 1.5 points. These results are based on the analysis of the drivers who participated in the survey, who represented most of the sample.

Fig. 6

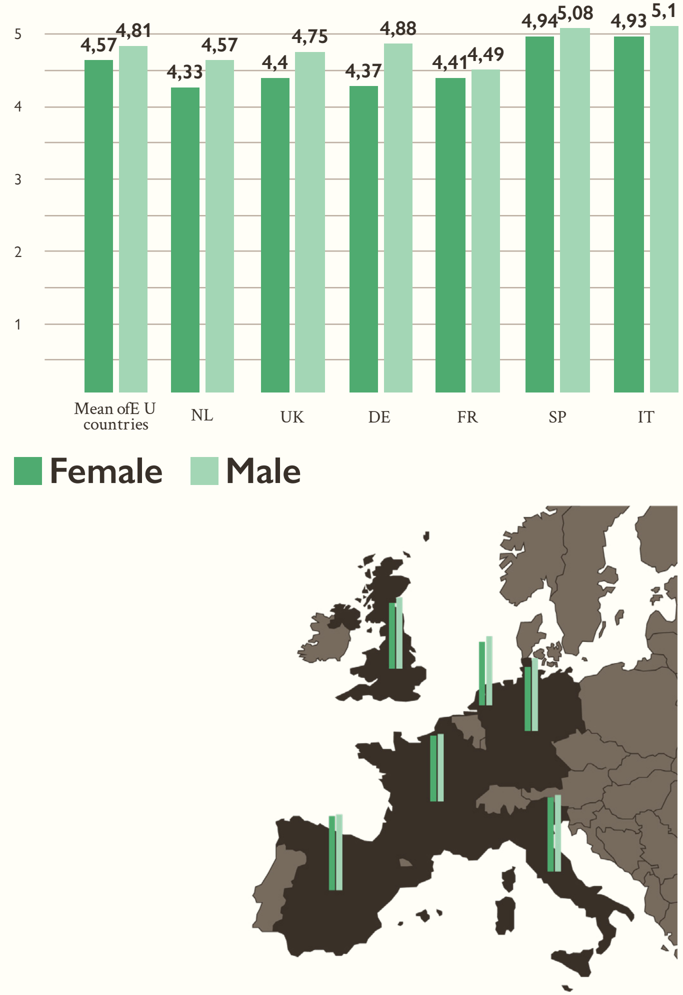


Figure 6. CAVs acceptability by country differentiating by genders (drivers)

2.2.2 Key aspects to enhance acceptability of CAVs for women

Making the most of synergies between the DIAMOND and the SUaaVE projects and turning the focus on the differentiated acceptability of CAVs and the need to enhance acceptability for women, we reach the following points ordered by increasing impact potential:

1 | Concerning **convenience** (“the belief that the vehicle will meet the user's driving needs.”):
▪ It has the highest capability to predict the acceptability of CAVs and is rated lower by women.
▪ It is associated with the following items: “meets my needs”, “efficient for me” and “maximizes my time with NDRT”.
▪ Therefore, it needs to be considered as a priority to improve acceptability of CAVs for women.

2 | In connection with **control** (“the belief that one will have control over the vehicle's behavior.”)
▪ The item “**perception to be in control when driving**” a CAV is a priority for women that needs to be improved, because women have a low **perception of CAV control** and also because it is more important for them than for men.

3 | Related to safety (“the belief that the vehicle will be safe.”)
▪ The priority to improve the perception that “AV would be safe” is common for both genders showing a high correlation with the acceptance.
▪ The priority to improve the perception that “AV would be safe” is common for both genders showing a high correlation with the acceptance.

4 | Linked to **pleasure** (“the belief that driving a CAV will be pleasant.”)
▪ The priority to improve pleasure is equal for women and men, its perception is also low for both.
▪ Although pleasure has a high capability to predict acceptability, it is not considered one of the most important attributes.

5 | Concerning **environmental sustainability** (“the belief that CAV will be environmentally friendly.”)
▪ It is the best perceived characteristic; thus, this perception must be maintained, even improved, to guarantee acceptance specially for women. Women rate it higher than men.

6 | Finally, in connection to **trust** (“the belief that the vehicle will behave as intended.”)
▪ Trust in CAV behavior is favorably perceived by

women and men. However, women rate it lower. It is only a priority for women if we want to increase acceptability.

▪ The other aspects under trust - “data hacking” and “detection of other road users” - are not identified as an issue by either men or women. That means people assume that once CAVs are on the street they will meet these requirements.

2.3 Acceptance of CAVs measured in the DIAMOND project

In the DIAMOND project the work was devoted to understanding the emotions and evaluating the experience of using a CAV. We centered on the identification and analysis of the differences between women and men, the intention being to generate indications and recommendations to promote gender friendly CAVs, within an overall mobility framework.

As a first approach, the DIAMOND project investigated gender differences in social media through a content analysis of hashtags and relevant keywords in the activity of Twitter users. In total, about 1 million tweets posted across partner countries from December 2019 to October 2020 were collected in order to provide more robust cross-cultural findings.

The analysis of activity on this social network involving CAVs, performed by Eurecat, found that women are more concerned with their social impact, social context and feelings while men tend to focus more on aspects related to technology and business. Women tend to use more negative language, using fewer positive words related to business and innovation and a more negative tone. Positive words that women used tended to be in relation to social and daily life. These initial results are consistent with the results obtained during the use of a CAV dynamic simulation.

2.3.1 An immersive experience in automated driving through a dynamic simulator

In the DIAMOND project we wanted to identify gender-driven needs, preferences and stressors related to the autonomous driving experience to transform them into indicators and recommendations for fairer CAVs. To do so, we used IBV's Human Autonomous Vehicle (HAV), a dynamic driving simulator that makes it possible to emulate different degrees of autonomy and dynamical behaviors and to monitor and detect the emotions of the passengers (Belda-Lois et al., 2021). The use of the HAV, represented in Figure 7, with direct emotion measurements, was combined with questionnaires to measure the subjective opinion of the passengers.

Fig. 6

Figure 7. Physiological measurements in the HAV simulator.

The experiment included a total of 40 drivers aged between 25 and 55, half of them women and half men, with and without care mobility responsibilities linked to having or not having children under 12. We wanted to make sure that a group of participants was performing care mobility displacements as this type of mobility has a high bias (Criado-Pérez, 2019), given that it is mostly performed by women. In each group there was a homogeneous age distribution. The aim of the work was to elicit and measure the emotional reactions of participants under a simulated CAV driving experience, while simultaneously exploring the influence of gender and having or not having children.

Six scenarios were designed and implemented in the HAV, with the help of a focus group, considering not only different environmental, traffic and driving conditions but also gender and other relevant intersectional variables in transport.

The first scenario simulated favorable and unfavorable weather conditions and we measured trust in CAV under both situations. The second and third scenarios proposed two different driving modes: (1) urgent, including abrupt overtaking, strong braking and high speeds and accelerations and (2) comfort, with smooth speeds and accelerations. In the fourth scenario, the participants had to perform a NDRT using a tablet. The fifth scenario implied a sudden failure of the system. Finally, the sixth scenario incorporated a dangerous driving situation. A car skipped a stop signal, arousing emotions. This situation was used to assess the safety perception.

The emotion was estimated by a bidimensional representation of arousal, the level of activation of the participant, ranging from calm (or low) to excited (or high), and valence, the level of pleasantness defined along a continuum from negative to positive. Both variables were recorded using bio-signal data sensors (see Figure 8) and included facial Electro Myography sensors (EMG), electrocardiogram measures (ECG) and Electro Dermal Activity sensors (EDA) (Chanel et al., 2007).

The results demonstrated that the designed scenario elicited differences in the emotional state when considering gender, in particular in the arousal level. This can be seen especially in the scenarios involving different driving modes (urgent/comfort) and while performing NDRT.

A questionnaire was designed in order to profile "driver" characteristics, mobility patterns and the identification of CAV design needs. The priorities and preferences were measured after an immersive experience of automated driving through the simulation.

Fig. 8

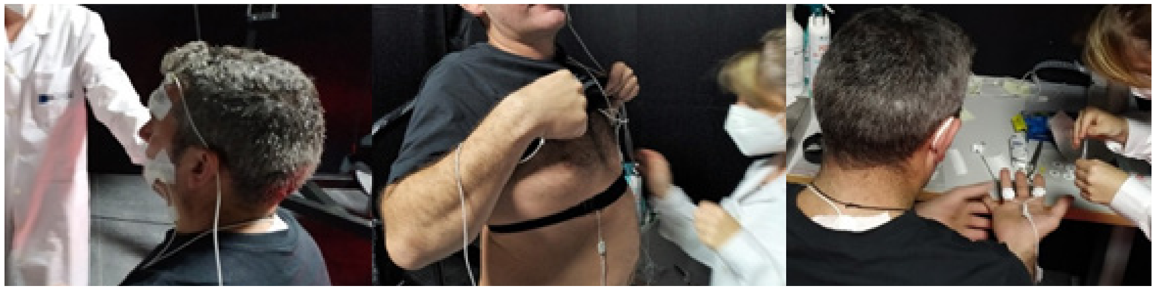


Figure 8. (left) facial Electro Myography sensors, EMG (center) sensor for obtaining the electrocardiogram, ECG (right) Electro Dermal Activity sensors, EDA.

2.3.2 Top factors affecting acceptance of autonomous vehicles

During the DIAMOND project, we identified and defined a set of factors that affect and determine women's acceptance of autonomous vehicles. This acceptance was linked to Fairness Characteristics (FCs) classified in a 3-level hierarchy, the labels of the top level being: (1) safety & security, (2) comfort, (3) mobility, (4) economy, (5) environment and (6) design options. A Bayesian Network analysis was performed to rank and weight all the level 3 FCs for women. As a result, DIAMOND obtained the top ten main factors considered by women when it comes to accepting or not accepting autonomous vehicles after the simulated driving experience[1]. Grouping them by their nature, we reach the following main concepts:

- **Non-Driving Related Tasks** (NDRT). Four of the top ten factors were related to the possibility of performing NDRT as the full attention of the driver is no longer required in L4+ CAVs. These included comfort and perception of boredom/joy when performing these activities and the degree of interaction with other passengers (including taking care of dependent people).
- **Social and environmental benefits.** Two of the top ten factors highlighted the importance of social benefits, the most important being the optimization of the well-being of other road users including pedestrians or cyclists. The potential reduction of the ecological impact was the other factor.
- **Acceptability.** One of the top ten factors was under this concept, mainly linked to technology, considering aspects such as the degree of agreement/satisfaction with driving a car without a steering wheel.
- **Trust and need of control.** Two of the top ten factors were under these two related concepts. They incorporated concepts such as the degree of trust when driving under different weather conditions and the importance of controlling driving variables (such as speed). Women rated the importance of control higher than men.
- **Maximize my time!** One top ten factor was under this concept. It integrates the concept of different driving modes (urgent/comfort), and it may be related to the need to use time wisely. Making the most of the available time was rated higher by women.

[1] These top ten factors are fully described in the DIAMOND public deliverable D4.3. "Computational analysis report", available in https://diamond-project.eu/download/d4-2-socio-economic-demographic-and-psychological-analysis-full-paper/#

2.4 Differentiated needs

2.4.1. Differentiated patterns of mobility. Trip-chaining and mobility of care

We have grouped the differentiated needs under three main labels: (1) related to the patterns of mobility, (2) focusing on the management of time and the need to optimize it and (3) other needs and requirements.

According to (Hanson, 2010), we use the term mobility "to signify the movement of people from one place to another in the course of everyday life". But as we will describe in this point, mobility is more than just moving from one place to another, especially if we consider the gender variable.

To begin with, there is a situation of poor mobility for women. The scale and impact of this situation is not well understood. Whether it is due to lower economic participation, reduced access to education, sport and culture, reduced mobility at night or expensive trip-chaining common to the mobility of care, many women travel (or do not travel) in a different way to men. The impacts of this are significant yet remain largely unmeasured and unspoken in the sector (Badstuber, 2019).

Second, women perform trip-chaining in a way that implies planning a route with multiple stops in order to include different errands/responsibilities (i.e. dropping children off at school en route to their workplace, or stopping at the market on their way home) whereas men mostly commute from A to B and back. Also, women walk more. While for men mobility is related more to employment and education, women add care mobility (when is not the main factor) to their daily displacements. Several publications have identified and covered these differences (Badstuber, 2019; Hung, 2013; Kalms, 2019; Saunders, 2019). Figure 9 represents the patterns of mobility of women and men.

Fig. 9

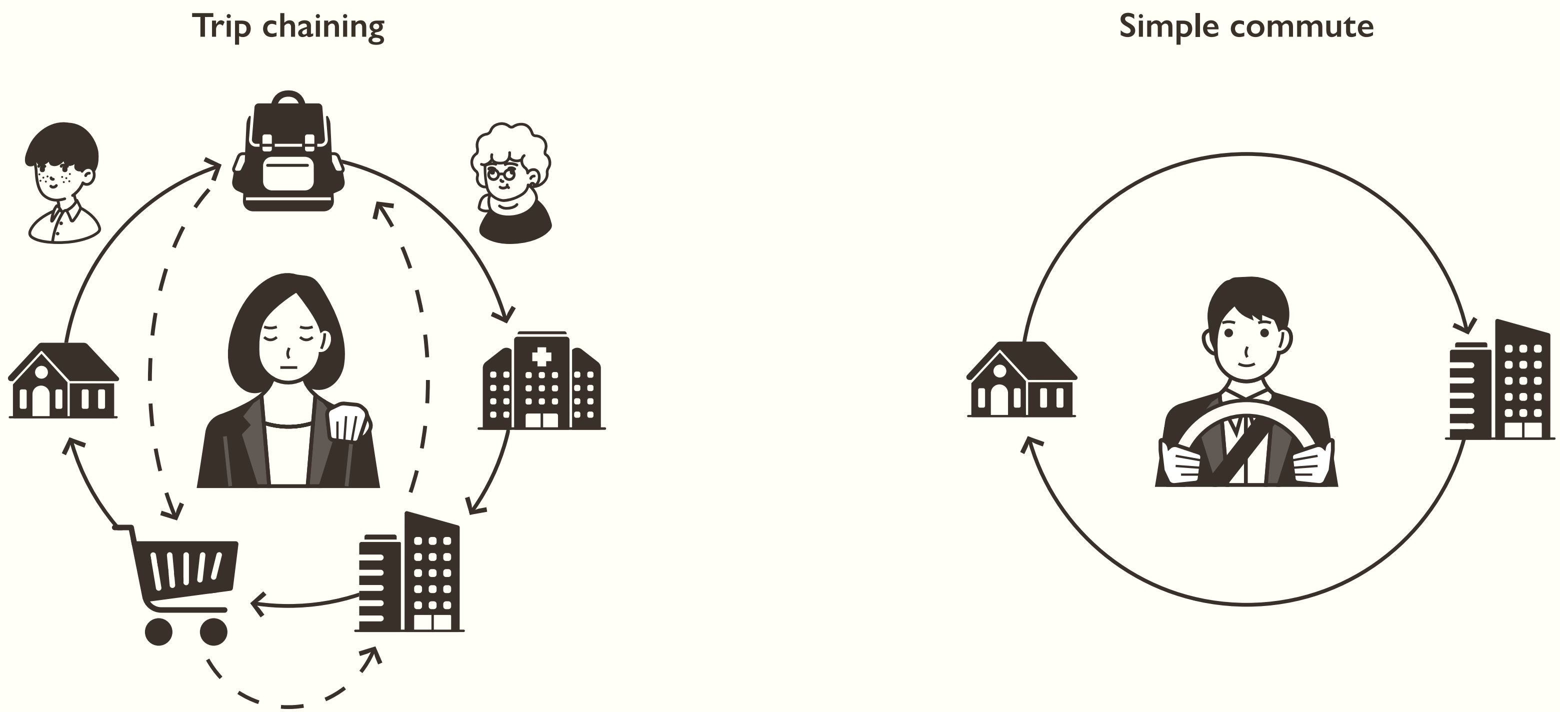


Figure 9. Trip-chaining vs simple commute. Most representative patterns of mobility of women and men.

And finally, in addition to the poorer and more complex mobility for women, we have to add the endemic levels of harassment on and around public transport that women and girls face every day and everywhere. Women modify their travel patterns to avoid danger, which has consequences for their participation in work, education and public life. Furthermore, women are still the primary group charged with the mobility of care (travel required due to caring for children or the elderly). With the projected growth of 'Mobility as a Service' and the banishing of single-use cars in cities, the situation for women and girls is likely to get worse, globally. Harassment, together with the elements described above, means that men and women have quite different mobility realities. And yet, even with the growing awareness of research, very little action has been taken to improve matters (Saunders, 2019).

Privately owned or shared CAVs need to be considered within the overall picture of mobility and current trends in the sector, whether used as a direct A to B commute or as part of a trip-chain. Therefore we have to assume, until it is proven (or not) to the contrary, that the same lack of equality applies for CAVs as for the whole mobility framework that has been very well identified when observed wearing gender-sensitive glasses (Badstuber, 2019; Kalms, 2019; Saunders, 2019).

From DIAMOND experimentation

Differentiated patterns of mobility. Women and men have different patterns of mobility, as we have seen in the different areas of study of the DIAMOND project. Among the participants in the experimentation, we found that 50% of women trip-chained at least once a week, while only 25% of men did so. This is consistent with the results of the bibliographic review, whereby trip-chaining is clearly identified as having a gender bias. What we found was that the factor "with/without children" was not significant in the frequency of trip-chaining, meaning that men with children do not change their "standard" pattern. When considering different mobility purposes, we have observed similar results between genders. However, the frequency of the displacements related to "own leisure activities" is higher for participants without children and "accompanying my family to their leisure activities" is higher for participants with children.

Mobility of care. When asked about their willingness to buy an AV after the experiment, women with children, who prior to the experiment expressed no interest in purchasing an AV, were the group that agreed the most with the statement. We cannot extrapolate this result to the whole universe of women, but if we understand that when people know the technology, they have a more favorable view of it, then we can assume that a first barrier has been taken down. The next thing will be to ensure that CAVs are designed taking the mobility of care into consideration, i.e., displacements with children, and the design should therefore consider their needs. CAVs should look for comfortable spaces for children and their caregivers, making it easier to perform caring activities or other ways of interaction.

2.4.2. Beyond Non-Driving Related Tasks, the need to "Maximize my time!"

To introduce this point, we recommend that you read the text below, which describes the differentiated use of time by women and men. And even how this unbalanced time distribution has become worse with the pandemic.

The 'double shift' burden has grown[1].

We already know that after decades of research, women do significantly more housework and childcare than men — so much so that women who are employed full-time are often said to be working a "double shift."

Now, women, and mothers in particular, are taking on an even heavier load. Mothers are more than three times as likely as fathers to be responsible for most of the housework and caregiving during the pandemic.

In fact, they are 1.5 times more likely than fathers to spend an additional three or more hours per day on housework and childcare. Single mothers have faced even greater loads — 10 percent more single mothers report spending an additional three or more hours per day on housework and childcare than mothers overall.

Working mothers aren't being recognized for time spent, either. More than 70 percent of heterosexual fathers in dual-career couples think that they are splitting household labour equally with their partner during the COVID-19 crisis, though only 44 percent of heterosexual mothers in dual-career couples agree.

And the home-care burden is spilling over to work. Nearly a quarter of mothers said they worried that their work performance was being judged negatively because of their caregiving responsibilities, compared with 11 percent of fathers.

As a consequence of the above, we can easily reach the conclusion that there is more pressure on women to use their time wisely than on men. That is

[1] Working Moms and the 'Double Shift' Burden. Women and Mental Health. Peachey Counselling https://www.peacheycounselling.ca/blog/2021/working-moms-and-the-double-shift-burden, Accessed 21/12/2021

probably the reason why during the experiment that took place in the DIAMOND project, when participants were asked about the type of NRDT they would like to perform, men and women presented different preferences. While men asked for more down time or relaxation activities, women wanted to add the time of the displacement to the productive time of the day.

In addition to this, trip-chaining implies more complex displacements, and probably more time in the vehicle. Therefore, for those people, mostly women, who perform this pattern of mobility on a daily basis, to optimize the time spent in the car, gaining quality or productive time could be an attractive argument. It seems to us that to properly address this need to “maximize my time!”, CAVs should incorporate new functions focused on trip-chaining needs, such as parking or car-waiting functions as well as functions such as self-configuration of the interior layout according to the tasks being performed, or based on a list of daily tasks(pick up children, supermarket…).

2.4.3. Other differentiated aspects

Although from what we have learnt in the DIAMOND project, trip-chaining and “maximize my time!” seem to be the most important differences, there are other elements we need to pay attention to, as considering them may improve CAV design, the definition of its functionalities, or how the interaction between passengers and vehicles is defined, or even the interaction with other road users and the overall infrastructure.

From the DIAMOND experiment

Social and environmental benefits. Autonomous vehicles need criteria to “decide” their behavior, criteria to drive. These “criteria” may combine different rules. According to our results, all groups agreed that the most important criterion was the optimization of the wellbeing of other road users. However, the importance given to the optimization of energy efficiency differed clearly: here women rated the importance of this criterion much higher.

Safety and security. Regarding safety aspects, the perceived reduction of the accident rate with AVs is similar for all groups. However, in the statement “AVs are safer than conventional cars under any conditions”, the agreement was close to neutral and in this case, women rated it lower, showing a slight disagreement. This could be a consequence of a long experience with vehicles not attending the specific and basic needs of women (basic ergonomics, safety of pregnant women…).

Trust and need for control. Women gave higher importance to keeping control of the driving features of the AVs. In point 1.2.4, we have alre-ady talked about trust, control and the need for control. The results of the simulation performed during the DIAMOND project showed differences in terms of gender. Future studies should at least delve deeper into the reasons behind these di-fferences and try to transform them into detailed recommendations for better CAV systems that are more fair for women.

2.5 Main recommendations

As in the other research areas of the DIAMOND project, to model and to present the results we have used the Fairness and Inclusiveness for Women Maturity Model developed in the DIAMOND project. Maturity Models are tools that are used in different fields to measure the ability of an organization to continuously improve in a particular discipline. The higher the maturity, the higher the chances that incidents or errors will lead to improvements either in the quality or in the use of the resources of the discipline, as implemented by the organization. The model consists of four increasing inclusiveness levels around three main topics: (1) capacity to meet required needs, (2) accessibility and (3) safety and security. For each topic we may include different issues, as we can see in Table 2.

In terms of needs, the importance of the NDRT will be notorious when applying a gender view and implies paying attention to care mobility and to defining related trip-chaining functionalities. Concerning accessibility, in addition to affordability (which has a strong gender bias) and attention to functional diversity, the implementation of shared vehicles will imply the introduction of a nomadic user concept with its unique features.

<table>
<tr><th>Capacity to meet required needs</th><th>Accesibility</th><th>Safe and secure</th></tr>
<tr><td>Confidence & disengagement for NDRT</td><td>Extremely flexible for a nomadic user</td><td>Ergonomics / Bio-mechanics safety</td></tr>
<tr><td>Interaction between passengers</td><td>Child friendly</td><td rowspan="2">Communication management to generate trust</td></tr>
<tr><td>Comfort in Non-Driving Related Tasks (NDRT)</td><td>Women ergonomics</td></tr>
<tr><td>Travel time / Trip-chaining</td><td>Gender and intersectional factors</td><td rowspan="2">Control management to generate trust</td></tr>
<tr><td>Social and Environmental Benefits</td><td>Inclusive design / Disability</td></tr>
</table>

Table 2. Key issues under the three labels of the maturity model.

This will involve an increasing importance of the flexibility of the layout of the vehicle. In safety and security, in addition to the traditional concept of safety, we need to add the need to be able to trust the system, and here women are more reluctant to give power to the vehicle. The key elements to remedy this situation may be proper training and communication between the vehicle and the passenger.

Of course, as AVs are still a field that is under development and involves a high degree of uncertainty, there are a variety of recommendations, some of which are more specific and others more focused on raising the awareness of the importance of coming up with solutions in AVs that are fair for women. The following information details the most important issues and needs that were identified and offers a series of recommendations.

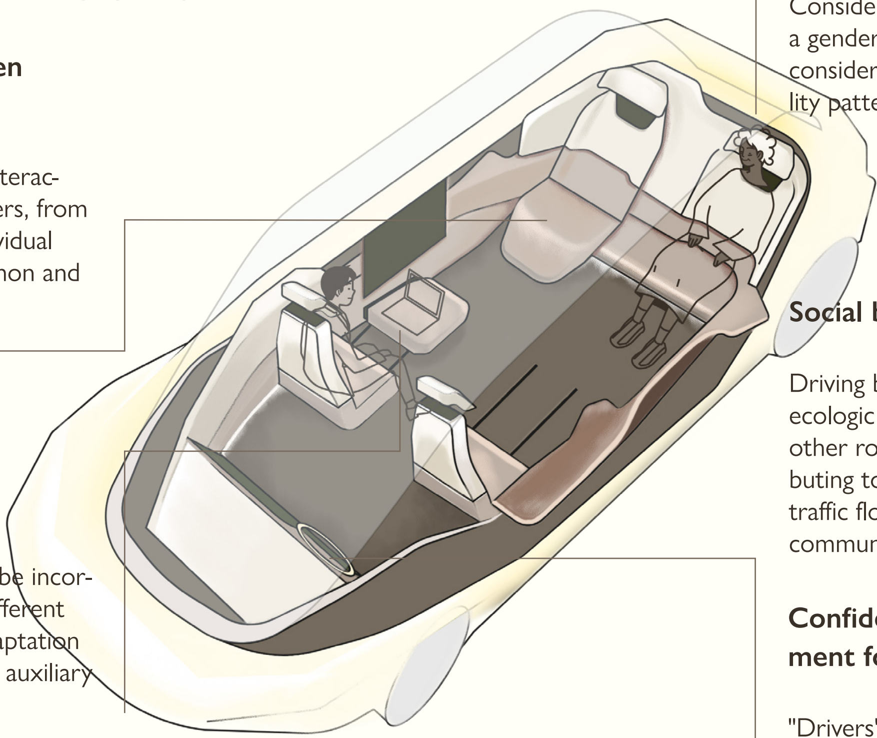
Capacity to meet the required needs

Interaction between passengers

Different degrees of interaction between passengers, from a more private or individual space to a more common and shared area.

Comfort in NDRT

Specific features must be incorporated to facilitate different types of tasks (e.g., adaptation of the illumination and auxiliary surfaces).



Travel time | Trip-Chaining

Considering travel time from a gender perspective implies considering the different mobility patterns.

Social benefits

Driving behavior with low ecologic impact, respectful of other road users and contributing to the improvement of traffic flow is beneficial to the community.

Confidence & disengagement for NDRT

"Drivers" may disengage from the driving tasks and feel confident when conducting other tasks while the AV keeps control.

Capacity to meet the required needs

Confidence & disengagement for NDRT

When the level of confidence and trust in AVs increases, it is easier for "drivers" to perform NDRT as they feel comfortable disengaging themselves from the driving issues. AVs should be designed to facilitate disengagement from driving issues to allow NDRT.

▪ "Drivers" may disengage from driving tasks with minimum supervision and feel confident when conducting other tasks while the AV keeps control.
▪ "Drivers" need to feel confident when conducting other tasks and specific automated functions are incorporated for this purpose such as strategies to avoid motion sickness, the adaptation of the driving mode for different NDRT…

Interaction between passengers

Interior layout and seating design solutions should provide different configurations to allow different degrees of interaction between passengers, from a more private or individual space to a more common space to promote interaction between passengers, including caring tasks (e.g., children).

Comfort in NDRT

NDRT must be performed comfortably by passengers or drivers. For this purpose, interior and ambient comfort facilities must be designed according to the needs of the different identified tasks.

▪ Specific features must be incorporated to facilitate different types of tasks (e.g., adaptation of the illumination and auxiliary surfaces).
▪ The interior layout should be easily reconfigurable for different tasks and postures (e.g., adaptable sitting and auxiliary surfaces, ambient comfort adaptable to the task, electronic facilities for working or entertainment…)

Travel time | Trip-Chaining

Considering travel time from a gender perspective implies considering the different mobility patterns; a specific characteristic of displacement by women is the connection of different displacements in a more complex way than men (e.g., dropping the kids off at school before going on to work).

▪ CAV should incorporate features to save time to the destination, facilitate trip chaining (chained displacements) and other specific functions that may be related to the differentiated pattern of female mobility.
▪ CAVs should offer options (driving mode, green wave options…) to improve travel time in the case of need. Automated driving function and non-driving functions should be incorporated focused on chained displacements (e.g., car parking or waiting functions, planning complete routes and task lists…).

Social and Environmental Benefits

Driving behaviour with low ecologic impact, respectful of other road users and contributing to the improvement of traffic flow is beneficial to the community.

▪ HMI should properly incorporate the communication and control of social benefits of the AV.
▪ Social and Environmental benefits must be communicated and perceived by occupants with proper indicators. Ideally, occupants are continuously informed by the system on social benefits allowing them to take informed decisions when selecting the automatic driving parameters (info for decision making). (e.g., by selecting this driving mode your car reduces its energy consumption by 30% of and is 10% more respectful of pedestrians).

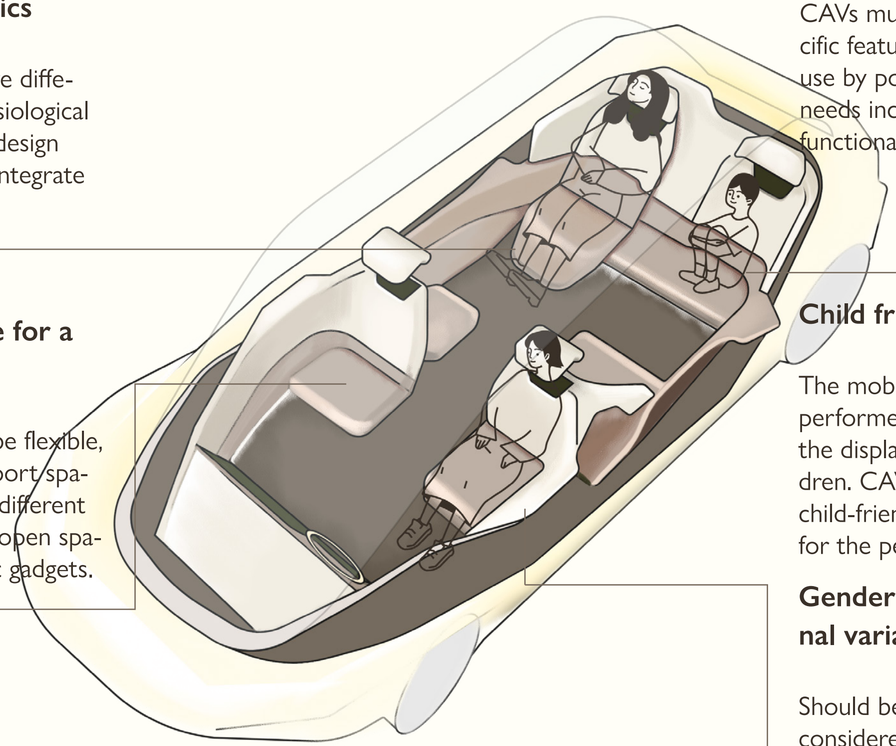
Accessibility

Women ergonomics

Women and men have different physical and physiological characteristics. CAV design should consider and integrate them.

Extremely flexible for a nomadic user

Cabin design should be flexible, offering different support spaces/surfaces allowing different configurations, more open spaces and fewer specific gadgets.



Inclusive design | Disability

CAVs must incorporate specific features to facilitate their use by population with spacial needs including any type of functional diversity.

Child friendly

The mobility of care, mainly performed by women, implies the displacement with children. CAV cabins should be child-friendly and comfortable for the person caring.

Gender and intersectional variables

Should be indentified and considered to stablish a proper user-centered design process and validation avoiding any disadvantage in the identified groups.

Accessibility

Extremely flexible for a nomadic user

Guidelines: Some studies see the development of AVs and their use in the development of a Sharing Service, that would imply a new concept of using the car with nomadic passengers. Thus, flexibility in CAV design should be incorporated considering that "the user of the car is a nomadic traveler with their own luggage".

Cabin design should be flexible, offering for example different support spaces/surfaces allowing different configurations, open spaces, fewer specific gadgets, flat surfaces, free from corners and bumps that make it easy to load and secure luggage and belongings and are easy to clean.

Children friendly

The mobility of care, mainly performed by women, implies displacements with children. CAV cabins should be a child-friendly environment.

▪ The issue of child safety should be addressed, from babies to teenagers. AVs should incorporate seats that can transform into boosters for some sizes. To achieve a child-friendly design, children should be considered as passengers with particular needs i.e. the space should be designed to be comfortable for the behaviour of children and for the person caring, monitoring and interacting with them.

Women ergonomics

Women and men have different physical and physiological characteristics. CAV design should consider women-specific physical and physiological characteristics.

▪ Women ergonomics must be applied in design such as anthropometrics, reach, strength and the variability of the female body and pregnancy should be considered.
▪ There are more anatomical and physiological differences between women and men such as temperature perception (for thermal comfort), voice pitch (for HMI), typical postures (for interior layout), proprioceptors (vehicle dynamics) and systems work as fully for women as they do for men.

Gender and intersectional factors

In addition to the physical and physiological differences CAV should consider gender factors for a fair design.

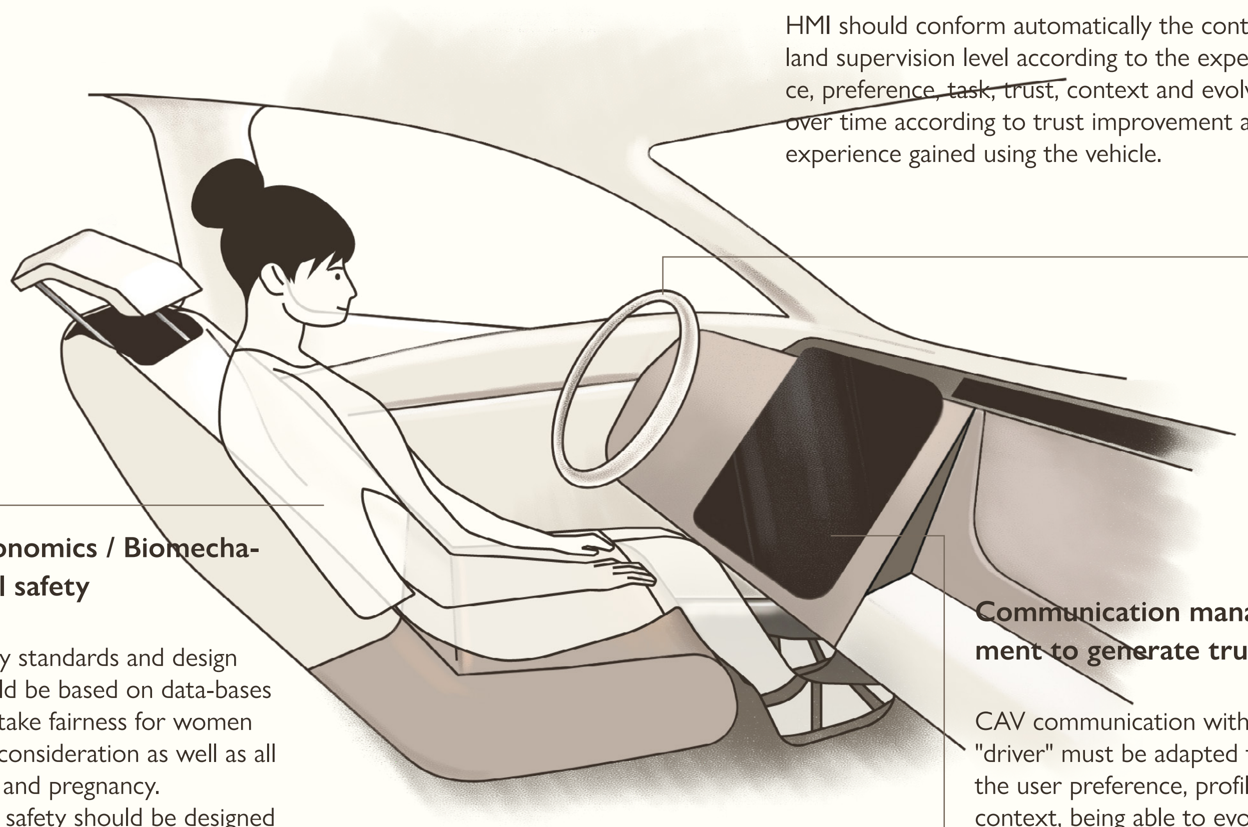
▪ Gender differences must be explored to study different patterns of use in order to define product users' needs and design solutions.
▪ Gender and other related intersectional variables should be identified and considered to stablish a proper user-centered design process and validation and to ensure none of the identified groups are disadvantaged. CAV HMI provides a Gender-Neutral Conversation.

Inclusive design | Disability

AV users are a varied group, with different needs and requirements. CAV design should consider the variability in the population's needs and its physical and physiological characteristics.

- CAV Design has to follow the principles of design for all.
- CAV must incorporate specific features to facilitate use by a population with special needs including different types of functional diversity.

Safe and secure



Control management to generate trust

HMI should conform automatically the control and supervision level according to the experience, preference, task, trust, context and evolve over time according to trust improvement and experience gained using the vehicle.

Ergonomics / Biomechanical safety

Safety standards and design should be based on data-bases that take fairness for women into consideration as well as all sizes and pregnancy.
CAV safety should be designed taking different women and girls uses and environments into consideration.

Communication management to generate trust

CAV communication with the "driver" must be adapted to the user preference, profile and context, being able to evolve over time according to the increased trust in and experience with the vehicle.

Safe and secure

Ergonomics / Biomechanicals safety

Traditionally, with few exceptions, the car industry has only considered male models when designing the safety systems of a car. CAV safety systems must be fair for women.

▪ Safety standards and design must consider anatomic (different breast sizes, …) and physiologic differences (e.g., voice pitch, field of vision) between men and women.
▪ Safety standards and design should be based on data-bases that take fairness for women into consideration as well as all sizes and pregnancy.
▪ CAV safety should be designed taking different women and girls uses and environments into consideration (e.g., trip-chaining, mobility of care) and further physiological differences such us driving styles, reaction times, preferences, stress and workload levels.

Communication management to generate trust

Appropriate communication between the AVs and the passengers or drivers may have a major impact on the trust in and satisfaction with the whole system. Thus, CAV communication with the "driver" is adapted to user preference, profile and context.

▪ "Drivers" should be able to configure the amount and complexity of the information they receive according to the situation or their characteristics.
▪ The HMI should provide automatic adaptation to the amount and complexity of information according to the experience, preference, task, trust, context in order to not overwhelm the “driver” and be able to evolve over time according to the increased trust in and experience with the vehicle.

Control management to generate trust

Drivers’ previous experience with advanced control systems, or their preferences (e.g., they like to have everything under control) condition the preferences for interaction with the AV in terms of control issues. Thus, CAV "driver" control and supervision must adapt to user preference, profile and context.

▪ "Drivers" should configure the control and supervision level according to the situation (context) or their characteristics.
▪ Ideally, the HMI should automatically configure the control and supervision level according to the experience, preference, task, trust, context — and — evolve over time according to the increased trust in and experience with the vehicle.

2.6 Conclusions

We are aware that the information presented in this report covers only a tiny albeit important part of all that is going on in the field of CAVs. In any case, we hope we have covered the following objectives.

- Those familiar with the concepts of gender equality and fairness will be able to gain technical knowledge about CAVs, and to understand how their vision and knowledge is important to develop better vehicles.
- Those familiar with the automotive sector and those who are aware of all the challenging developments taking place in autonomous vehicles will benefit by its human-centered approach which stresses women's needs and perceptions.
- Those absolutely new to either of the two fields will discover to what degree the development of the automotive sector means a breakthrough in terms of the traditional concept of a privately-owned vehicle. They will also identify the potential of applying the concepts of equality and fairness to such a technological field.

In any case, we hope that by reading these guidelines you will have found fresh ideas and concepts that will help you to apply sex and gender differences to your work, no matter whether you are a designer, a car manufacturer or a policy maker, to improve the acceptance of CAVs, especially for women, and to combat the history of women unfairness of the automobile industry developments.

IBV Instituto de Biomecánica de Valencia
DIAMOND
Horizon 2020
European Union Funding
for Research & Innovation

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Project DIAMOND

The DIAMOND project has analysed and compiled data with the aim of converting them into useful knowledge and develop materials and protocols for the transport sector to promote more inclusive and efficient transport systems from a gender perspective. DIAMOND used technologies for compiling and analysing data in Europe such as machine learning and data collection methodologies that enable specific measures to be identified and designed to meet the needs and expectations of female users and professionals in the transport sector. This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 824326.

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